SPACE WEATHERING RATES IN LUNAR AND ITOKAWA SAMPLES.

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Introduction: Space weathering alters the chemistry, microstructure, and spectral properties of grains on the surfaces of airless bodies by two major processes: micrometeorite impacts and solar wind interactions. Investigating the nature of space weathering processes both in returned samples and in remote sensing observations provides information fundamental to understanding the evolution of airless body regoliths, improving our ability to determine the surface composition of asteroids, and linking meteorites to specific asteroidal parent bodies.

Despite decades of research into space weathering processes and their effects, we still know very little about weathering rates. For example, what is the timescale to alter the reflectance spectrum of an ordinary chondrite meteorite to resemble the overall spectral shape and slope from an S-type asteroid? One approach to answering this question has been to determine ages of asteroid families by dynamical modeling and determine the spectral properties of the daughter fragments [e.g., 1-2]. However, large differences exist between inferred space weathering rates and timescales derived from laboratory exeriments, analysis of asteroid family spectra and the space weathering styles [e.g. 3-6]; estimated timescales range from 5000 years [5] up to 10^8 years [3]. Vernazza et al. [4] concluded that solar wind interactions dominate asteroid space weathering on rapid timescales of 10^4-10^6 years. Shestopalov et al. [6] suggested that impact-gardening of regolith particles and asteroid resurfacing counteract the rapid progress of solar wind optical maturation of asteroid surfaces and proposed a space weathering timescale of 10^5-10^6 years.

Results and Discussion: In contrast to the experimental and modeling efforts described above, we directly determine the space weathering rate for the formation of altered surfaces of lunar regolith grains returned by the Apollo missions and asteroid regolith grains from Itokawa returned by the Hayabusa mission. Using electron microscopy techniques, we determine the chemistry and microstructure of the weathered grain rims which allows us to differentiate solar-wind damaged rims from those formed via impact processes. The surface exposure ages of the grains are obtained by measuring the density of solar flare particle tracks that have accumulated during their surface residence. For example, the width of solar wind amorphized rims on lunar anorthite increases as a smooth function of exposure age until it levels off at ~180 nm after ~20 My [7]. We have calibrated this procedure by measuring the space-weathered rim width and track density in anorthite and olivine from the surface of lunar rock 64455 [8] that was never buried, and has a well constrained surface exposure age based on isotopic measurements. These analyses reveal that space weathering effects in mature lunar soils accumulate and attain steady state in 10^6-10^7 y [7].

Regolith grains from Itokawa also show evidence for space weathering effects, but in these samples, solar wind interactions dominate over impact-related effects such as vapor-deposition [9,10]. Analyses of five Itokawa olivine and plagioclase grains, with weathered rims, show a range of solar flare track densities indicating surface exposure ages ranging from ~27,000 y to 10^5 years [11]. Provided that the track densities and the solar wind damaged rim widths exhibited by the Itokawa grains are representative of the fine-grained regions of Itokawa, then the space weathering rate to convert its reflectance spectrum to that of an S-type asteroid is on the order of 10^5 y.

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